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DUST AND THE TRACTOR ENGINE

BY

A. H. HOFFMAN

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DUST AND THE TRACTOR ENGINE[1]

By A. H. HOFFMAN

CONTENTS

[1] No attempt is made in this paper to illustrate or to explain apparatus and methods for testing air cleaners. For complete description see Hoffman, A. H., "Efficiency of Dust Separation in Air Cleaners for Internal Combustion Engines," *Transactions A. S. A. E.*, vol. 16 (1922). Reprints in limited numbers may be had by addressing Agricultural Engineering Division, University of California, Davis, Calif. Full data of all tests are on file and accessible at the same place.

Dust causes rapid wear.—When it is remembered that fifty-five per cent of the average dust floating around in California fields (fig. 1) is shown by test to be sand, it will not be hard to understand why a tractor engine needs an efficient air cleaner. An engineer of a prominent California tractor manufacturing company recently stated that their latest model tractor would run in dusty conditions under full load for three thousand hours with no adjustments whatever, and for six thousand hours with only minor adjustments, *provided it had a satisfactory air cleaner;* but that without an air cleaner the engine would be ruined in fifteen hours' use.

Fig. 1.—Typical conditions under which the tractor in California must do its work. Dust entering by way of carburetor and breather pipe mingles with the lubricating oil and makes a grinding mixture which quickly wears out many parts of the engine.

EFFICIENCY OF AIR CLEANERS

Air cleaners not all equally efficient.—It has long been known that the numerous makes and types of air cleaners on the market differ in their ability to remove dust from the entering air, in the degree to which their use imposes vacuum or choking on the carburetor intake, and in their effect on the maximum possible power to be obtained from the engine; yet there has been no publication of authoritative tests previous to those here given by which the user might know what service he might reasonably expect from any given air cleaner.

Tests made at Davis.—To determine their dust-separation efficiency, vacuum imposition and effect on power, a long series of tests was made at the Branch of the College of Agriculture, Davis, Calif. Twenty-six cleaners (described later) were tested. A twenty-five h.p. four-cylinder engine was used on which to make the tests in order to have

conditions as nearly as possible like those encountered in actual work. Since in a field test it would be very difficult to avoid errors due to differences in kind of soil, dryness of soil, direction and strength of the wind, temperature and moistness of the air, etc., it was deemed better to make the tests in the laboratory where both load and speed could be made the same for all cleaners tested, and where a standard dust might be fed to all cleaners in the same manner, in the same amounts, and at the same rates.

The No. 1 standard dust used in the efficiency tests was made up from fifty-pound soil samples taken from ten cultivated fields or orchards scattered throughout the principal tractor-using areas of this state. The ten soils were dried and pulverized and the finest parts taken out by an air-floating process. The dusts so obtained were mixed to make the No. 1 standard dust; hence it is a composite which may be regarded as fairly representing the average dust in our fields at a height of about four feet above ground.

How the dust was fed to the cleaners.—The standard quantity of dust fed in was fifty grams (1.76 ounces), and the usual standard time was about thirty minutes. The dust was fed to the cleaner under test by placing it in a tin tube from which a plunger pushed it out slowly against a revolving bristle brush wheel by which it was swept in a very fine cloud directly into the air stream entering the cleaner.

Finding the efficiency of the cleaner.—The air leaving the cleaner passed next through an 'absolute cleaner' which caught the dust not caught by the cleaner under test, and then into the tractor engine. The cloths of the absolute cleaner were thoroughly dried and accurately weighed before and after the test, the difference in weight being the weight of dry dust not caught by the cleaner under test. Where this weight was five grams the efficiency would be 90 per cent.

Three standard efficiency tests.—Three standard tests were run on each cleaner as follows:

1. A test at normal speed (1200 r.p.m.), normal load (20.4 h.p.), and quick dust feed (50 grams in 30 minutes).
2. A test at normal speed, light load (12.6 h.p.), and quick dust feed.
3. A service test, at quick dust feed, in which working conditions were approximated. In this run, variable load, variable speed, idling, backfiring and quick pick-up with wide open throttle, were features. At intervals load and speed were brought to normal and readings of vacuum were taken. (See table 2, p. 478, and fig. 6.)

Special tests were run when circumstances required. Among these were *a low water level test, a fill-up test,* and *a chaff test.* On water type cleaners (also on one oil type cleaner) where the level of the liquid would be lowered by use, an efficiency test was run with the liquid at the low level mark (if any). On cleaners which from their construction might presumably have their efficiency or vacuum affected by the entering dust a so-called fill-up test was run. This was not a standard efficiency test and for it the material fed in was a prepared dust known as No. 2 standard. It was uniform, but was much coarser and denser than the No. 1 standard. The purpose of the fill-up tests was to obtain a rough estimate of what might be expected of the cleaner *when neglected and subjected to gross abuse.* The amount of dust fed in fill-up tests was as much as seven pounds in some cases. The rate of feeding was also very rapid and for this reason little importance is to be given to those instances in the fill-up test where the cleaner did not show up well. However, where a cleaner under this very severe test was able to maintain good efficiency and low vacuum, its ability to stand abuse would in a measure seem to be established. (See table 3, p. 479.)

The chaff test was designed for cleaners not provided with an adequate screen and of such interior construction as presumably to have the vacuum affected by the entrance of insects, leaves, and other organic refuse. Ten grams of dry wheat chaff passed through one-fourth inch mesh screen was allowed to be drawn into the air stream entering the cleaner, and the effect on the vacuum due to the cleaner was noted. (See table 4, p. 480.)

Vacuum tests.—The vacuum or choking effect was measured by use of a U-tube manometer at intervals during the efficiency test runs and also during tests made to find the effect of the cleaners on the power of the engine. (See table 2 and figs. 7 and 8.)

Power tests.—The tests to find effect on power were run as follows. After warming up thoroughly, the engine was run, *cleaner off,* with wide open throttle and carburetor adjusted for highest power. Next came a similar run with *cleaner on,* the carburetor being readjusted; then immediately another run with *cleaner off.* The highest power at standard speed obtained in the run with cleaner on was divided by the average of the highest powers obtained at standard speed in the first and third runs. The per cent so obtained was used as the means of comparing the power effects of the several cleaners. (See table 2, p. 478, and fig. 8.)

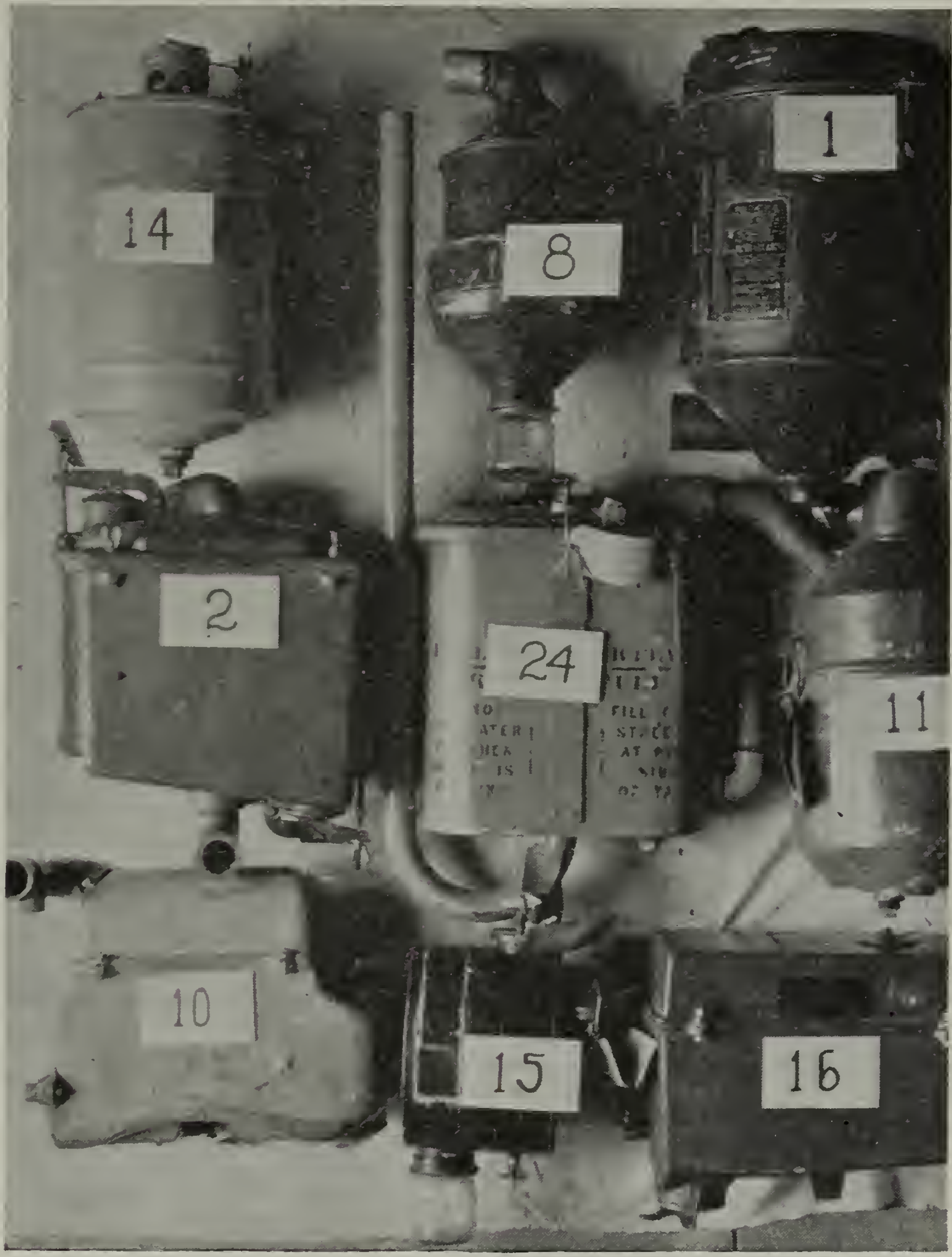

Fig. 2.—Water type cleaners.

1. J. I. Case Threshing Machine Company.
2. Cleveland Tractor Company. (Cletrac W.)
8. W. H. L. Donaldson.
10. Ford Motor Company (Fordson).
11. International Harvester Company. (10–20 Titan.)
14. Ross-Wortham Company. (R. W.)
15. Stewart-Warner Speedometer Corporation.
16. Tractor Appliance Company. (Taco Siphon.)
24. Samson Tractor Company. (Model M.)

THE CLEANERS TESTED

Source.—The manufacturer of each of the thirty[2] cleaners tested was invited to determine the size of cleaner to fit the engine on which the tests were to be run and to choose the particular cleaner to be tested. With a single exception manufacturers availed themselves of this privilege.

Classification.—For purposes of comparison the cleaners were classified into three groups according to their mode of operation, as water type, dry type, and oil type.

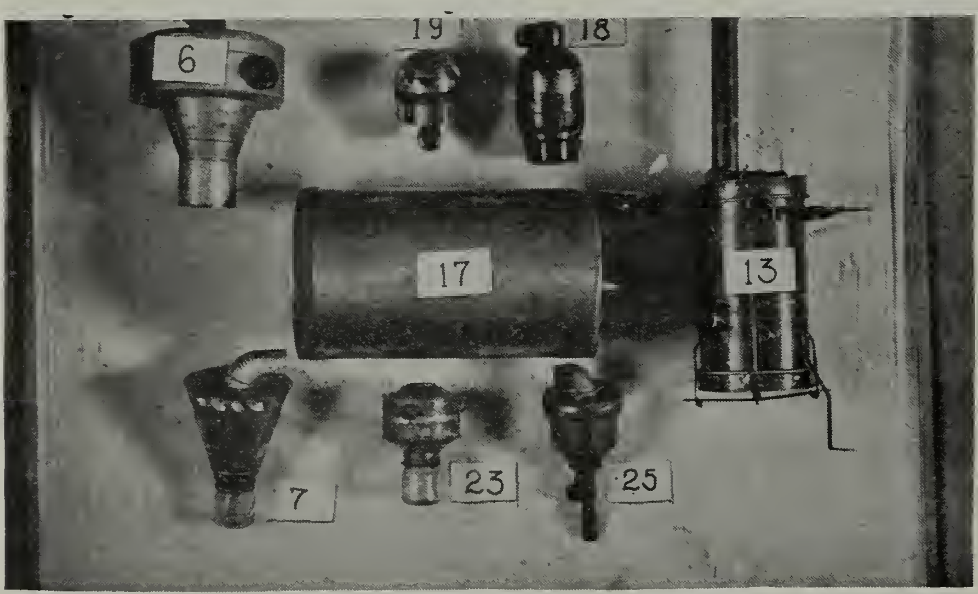

Fig. 3.—Dry type cleaners.

6. Donaldson Company, Inc. (45 h.p. tractor.)
7. Donaldson Company, Inc.
13. Liljegren and Dugain, ''Success'' (for Fordson).
17. Copied from eiderdown cleaner shown in Chilton Tractor Journal, June 1, 1919, p. 41.
18. United Manufacturing and Distributing Company. (Collector type.)
19. United Manufacturing and Distributing Company. (Ejector type.)
23. Bennett Carburetor Company.
25. Stromberg Motor Devices Company.

Of the eleven water type cleaners tested, seven (nos. 1, 2, 10, 11, 14, 24, and 24A)[2] passed the dusty air under the edges of a float, two (8 and 27)[2] used the centrifugal principle, and two (15 and 16) used the atomizer principle.

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[2] Twenty-six cleaners were received in time for all the tests, four (nos. 24A, 25A, 25B, and 27) in time for power tests only. See tables nos. 1 and 2.

Of the ten dry type cleaners, two (13 and 17) used cloth filters, the other eight employed the centrifugal principle, the whirl being obtained by means of vanes, tangentially placed inlets, or both (6, 7, 23, 25, 25A[3] and 25B[3]), or by a rotating member (18 and 19). Some of these (25, 25A, and 25B) had an ejector operated by exhaust gas from the engine to throw the separated dust to the outside air, while another (19) ejected the dust by the centrifugal action of the rotating member. These last cleaners therefore did not require to be emptied.

Fig. 4.—Oil Type Cleaners.

3. Dailey Bros.
4. Dailey Bros.
5. Donaldson Co., Inc.
9. Fageol Motors Co.
12. A. E. Palmer (Experimental).
20. Vortox Mfg. Co. (Pomona).
21. Vortox Mfg. Co. (Pomona).
22. Vortox Mfg. Co. (Pomona).
26. Dailey Bros. (Model 1).

Of the nine oil type cleaners, one (12) employed the atomizer principle; the other eight had oiled filters, one (9) of cloth, three (3, 4, 26) of fibrous material, two (21 and 22) of fibrous material combined with oil centrifugal, one (20) of wire combined with oil centrifugal, and one (5) of fibrous material combined with dry centrifugal.

[3] For 24A, 25A, 25B, and 27 see tables nos. 1 and 2.

A homemade cleaner.—One cleaner, no. 17 (called no. 17′ when outer shell is left off, as in fig. 5) was made up by a local tinsmith. It is pictured in the *Chilton Tractor Journal,* June 1, 1919, as an example of an obsolete type. Made up as shown and with two thicknesses of eiderdown blanketing wrapped on, nap side out, over the cylinder of one-half inch mesh hardware cloth, its performance under all tests was very satisfactory. A cover is not essential to its operation. It may be placed in any position.

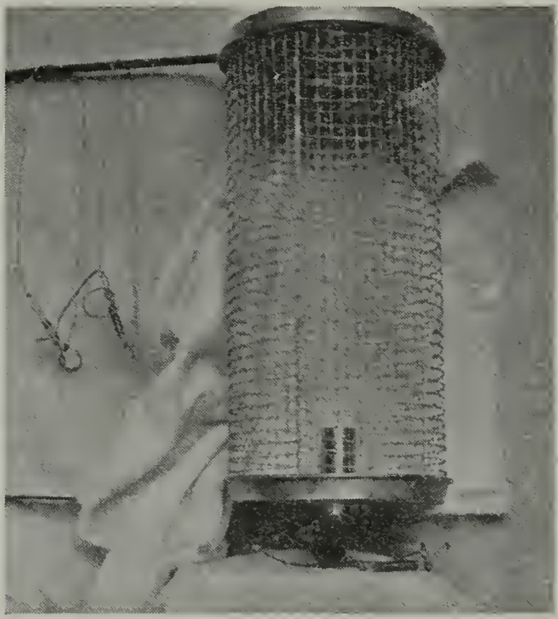

Fig. 5.—A homemade cleaner.

Eiderdown cleaner (no. 17 and 17′) cover removed, cloth laid back. A (9″ × 18″) cylinder of wire screen soldered to heavy tin pans. Tube (size of carburetor inlet) extending to inside. Iron bars suitable for attachment to tractor riveted to ends. Two thicknesses of eiderdown blanketing, nap side out, tied on.

Identification table.—The cleaners tested are listed in table 1, the essential dimensions by which they may be identified and compared being given. A list of air cleaner manufacturers' addresses may be obtained from the Division of Agricultural Extension, University of California, Berkeley, or from the Division of Agricultural Engineering, University Farm, Davis, California.

The results of the tests.—Table 2 gives a general summary of the tests. Table 3 summarizes the fill-up tests, and table 4 the chaff tests.

TABLE 1

Identification of Cleaners Tested

No.	Make or name	Type	Weights: Clean dry lbs.	Weights: Ready for use, lbs.	Outlet Diam. inside, inches	Inlets: No.	Inlets: Diam. inches or size of opening	Size of body proper, Height, Length, Width, inches
1	Case	Wet	18-3/4	39-1/4	2-1/2	1	2-1/2	19-1/2 x 12D
2	Cletrac W	Wet	57-1/4	74-1/2	1-1/2	1	1-1/2	14 x 13 x 9
3	Dailey	Oil	11-3/4	12	1-3/4	1	1-7/8	18 x 7-1/2D
4	Dailey	Oil	12	12-1/4	1-7/8	1	1-7/8	18 x 10D
5	Donaldson	Oil & Dry	5-3/4	5-3/4	1-1/2	15	1-1/4 x 3/8	16 x 8D
6	Donaldson	Dry	5-1/4	5-1/4	2-1/4	1	2-1/4	12 x 11D
7	Donaldson	Dry	2	2	2	15	1 x 1/4	11-1/4 x 8D
8	Donaldson	Wet	15	10	1-7/8	1	1-3/4	17 x 9D
9	Fageol	Oil	9-1/4	9-1/2	1-1/2	1	1-1/2	13-1/2 x 10-3/4D
10	Fordson	Wet	40-1/4	53-1/4	1-3/4	1	1-1/2 x 1-1/2	12 x 14-1/2 x 6
11	I.H.C.	Wet	18	34	2	1	2-1/2	18-1/2 x 10-1/2D
12	Palmer	Oil	9-1/2	15	1-11/6	1	1 x 3	18 x 8-1/2D
13	Success	Dry	10-1/2	10-1/2	1-7/8	1	1-7/8	15 x 8D
14	R.W.	Wet	8-3/4	18-1/2	1-3/8	6	1	15 x 9D
15	Stewart-Warner	Wet	7	16-1/4	1-3/8	2	1-3/4 x 2	13 x 9D x 6-1/2
16	Taco Siphon	Wet	44-1/2	56	2	1	2-1/2	12-1/2 x 16 x 7-1/2
17	Eiderdown (closed)	Dry	9	9	1-7/16	1	2	26 x 12-1/2D
17′	Eiderdown (open)	Dry	5	5	1-7/16	1	565 sq. in.	19 x 10D
18	United collector	Dry	8-3/4	8-3/4	1-1/2	1	1-1/2	10-1/2 x 5D
19	United ejector	Dry	2-1/2	2-1/2	1-7/16	1	3-1/4	7 x 5D
20	Pomona	Oil	4	5-3/4	2	1	2	13-1/2 x 4-5/8D
21	Pomona	Oil	3-1/4	5	2	1	2	13 x 4-5/8D
22	Pomona	Oil	9	16-1/2	2	1	2-1/2	15 x 10D
23	Bennett	Dry	4-1/8	4-1/8	1-3/4	3	1-3/16	9 x 6D
24	Samson	Wet	27-1/4	42-1/2	1-3/8	1	1-3/8	14 x 12-1/2 x 7
24A	Samson	Wet	28-1/4	37-1/4	1-1/4	1	2 x 6-1/2	15 x 10D
25	Stromberg	Dry	3-1/2	3-1/2	1-5/8	12	7/8 x 3/8	14 x 6D
25A	Stromberg	Dry	3-1/2	3-1/2	1-5/8	12	7/8 x 3/8	14 x 6D
25B	Stromberg	Dry	4-3/4	4-3/4	1-3/4	12	1-1/8 x 3/8	16 x 7-1/2D
26	Dailey	Oil	10	10-1/2	1-9/16	1	1-1/2	17-1/2 x 10D
27	Bennett	Wet	8-1/4	15-1/4	1-3/4	1	1-3/4	12 x 9D

TABLE 2

SUMMARY OF TESTS

No.	Make or trade name	Dust separating efficiency per cent			Vacuum			Maximum power with cleaner on	Ratio h.p. with cleaner on to h.p. with cleaner off. per cent
					At 20.4 h.p. 1200 R.P.M. inches water		At maximum h.p. and 1200 R.P.M. inches water Cleaner cleaned out after efficiency tests		
		Average all tests	Service run	Low Water or oil	Cleaner clean	150 gram No. 1 Std. dust in			
1	Case	96.0	96.1	95.2	1–3/4	1–11/16	2.6	27.0	100.0
2	Cletrac W	89.3	85.8	83.6	3–13/16	5–1/8	8.5	26.6	98.7
3	Dailey	99.5	99.9		6–5/16	22–7/16	Run	lost due	to error
4	Dailey	99.8	99.9		5–7/16	18	10.7	26.6	98.7
5	Donaldson	97.8	98.0		3–1/8	20–9/16	4.5	27.2	100.6
6	Donaldson	74.7	67.4		1–5/8	2–7/16	3.8	27.1	100.3
7	Donaldson	51.0	50.3		2–1/16	2–5/16	4.2	27.1	100.2
8	Donaldson	96.5	97.3	95.0	2–5/8	4–3/4	7.4	27.0	100.0
9	Fageol	98.5	99.5		4–1/2	16	12.8	25.7	95.2
10	Fordson	88.9	89.8	85.5	7/8	1–1/2	3.3	26.8	99.3
11	I.H.C.	94.6	94.4	92.3	2–11/16	2–7/8	3.5	27.4	101.7
12	Palmer	96.6	96.9	94.7 oil	4	6	6.3	26.9	99.6
13	Success	98.7	97.8		1–1/2	27–1/4+	2.2	27.0	99.9
14	R.W.	93.1	92.6	92.6	3–1/4	3–5/8	8.3	26.9	99.7
15	Stewart-Warner	95.7	95.8	Const. level	4–5/8	5–9/16	11.1	26.5	98.3
16	Taco Siphon	92.4	94.0	85.9	2–1/2	3–3/16	5.8	27.0	99.8
17	Eiderdown (closed)	99.4	99.5		2–5/16	2–5/8	5.6	27.2	100.7
17′	Eiderdown (open)	Test	not run				4.8	27.0	99.9
18	United (collector)	73.3	72.5		9	9	12.7	26.5	98.2
19	United (ejector)	62.2	58.3		3–3/16	4–1/2	9.3	27.0	99.8
20	Pomona	98.4	98.2		2–3/16	2–5/8	7.2	26.7	98.8
21	Pomona	98.8	98.6		2–5/16	2–3/4	5.3	27.5	102.0
22	Pomona	97.4	97.1		1–5/8	1–11/16	4.8	26.6	98.3
23	Bennett	42.7	37.6		5–1/2	6–1/16	8.9	26.6	98.2
24	Samson	95.9	95.2	Not run	5–3/8	5–3/8	10.1	27.0	100.1
24A	Samson						6.9	26.8	99.1
25	Stromberg	88.5	87.4		4–3/8	6–7/8	11.1	26.5	98.3
25A	Stromberg						8.8	26.4	97.6
25B	Stromberg						7.0	27.2	100.6
26	Dailey	99.7	99.6		8–1/8	9	17.4*	26.7	98.9
27	Bennett						9.3	26.8	99.1

* Abnormal; chaff of chaff test not all out.

TABLE 3

Summary of "Fill-up Tests"

Cleaner No.	Test run No.	Lgth. run Min.	B.H.P.	Room Temp. °F	Dust No. 2 Std. lbs.	Dust caught by absolute cleaner lbs.	Water or oil going over lbs.	Vacuum due to cleaner, inches water		Rate of air flow §	Note
								Min.	Max.		
1	114	48	20.4	104	9	1/16	0	1-7/8	11	53	1
2	102	54	20.4	91	5	1/8	.9*	5-1/8	7	53	2
5	71	31	20.4	83	50 gram	1 gram	0	7-3/16	20-9/16	55	3
9	22	....	20.4	78	0.16	†	....	6-3/8	26-3/4	53	4
10	108	28	16	99.7	5	.05	0	1-1/2	2-5/16	47	5
13	16	8	16	82	0.16	†	....	11-1/4	24-5/8	51	6
15	68	36	20.4	67	3	.25	0	5-7/16	16-1/8	....	7
16	50	38	20.4	85	5	.02	0	2-3/4	5-1/16	55	8
17	138	23	20.4	92	5	†	....	3	4-17/32	53	9
20	76	18	20.4	95	2.5	‡	0	2-3/4	3-1/8	54	10
21	33	30	20.4	76	3	1	0	2-3/8	14-5/16	58	11
22	81	36	20.4	100	7	1/8	0	1-3/8	3-7/16	55	12
24	38	56	20.4	86	5	1/8	Trace	4-7/16	26-3/8	....	13
26	57	62	20.4	76	5	†	0	8-5/8	10	54	14

Note 1. One pound sand, etc., found in horizontal inlet tube in base of cleaner at close of test. Dust of previous runs (200 grams) left in.
2. Cleaned out before test.
3. Dust of previous runs (100 grams) left in. Not deemed necessary to use any No. 2 Standard dust.
4. Dust of previous runs (100 grams) left in.
5. Dust of previous runs (200 grams) left in. Tested at Fordson load.
6. Dust of previous runs (100 grams) left in.
7. Dust of previous runs (150 grams) left in.
8. Dust of previous runs (250 grams) left in.
9. Dust of previous runs (150 grams) left in.
10. Dust of previous runs (150 grams) left in. Dust going through rather freely after 4th half pound dust in.
11. Dust of previous runs (200 grams) left in. Sand began passing to trap soon after oil ceased to spray.
12. Dust of previous runs (150 grams) left in.
13. Cleaned out before this test.
14. Dust of previous runs (150 grams) left in.

* Amount abnormal since rapid rate of dust feed raised water level about 5/8 inch above high mark.
† Not weighable on 1/4 oz. sensitive scale.
‡ Not weighed.
§ Cu. ft./min. 60°F. and 14.7 lbs./sq. in.

TABLE 4

SUMMARY OF CHAFF TESTS

(Ten grams dry wheat chaff was fed to cleaners not having adequate screen, to find effect on vacuum.)

Cleaner No.	1	5	8	10	17	20	24	26
Run No.	113	72	129	107	137	77	37	58
Length run, Min.	10	11	30	8	8	47	33	43
B.H.P.	20.4	20.4	20.4	16	20.4	20.4	20.4	20.4
Rate of air flow cu. ft. per min. 60°F and 14.7 lbs./sq. in.	53	54	53	47	53	54	55	54
Vacuum due to cleaner Min.	1–3/4	3–5/16	4–3/8	1–1/8	2–3/4	2–11/16	5–3/8	9–5/8
Vacuum due to cleaner Max.	1–3/4	3–3/4	10–3/16	1–5/32	2–7/8	6–3/4	32–15/16	28–3/4
Remarks	Note 1	Note 2	Note 3	Note 4	Note 5	Note 6	Note 7	Note 8

NOTE 1. Dust (150 grams) of previous runs left in.
2. Filter cleaned out and reoiled before test.
3. Drained out (but not flushed) and refilled before test.
4. Dust (200 grams) of previous runs left in. Water level low.
5. Dust (150 grams) of previous runs left in.
6. Filter cleaned out and reoiled before this test.
7. Dust (150 grams) of previous runs left in. No. 24A (received too late for test) has an adequate screen.
8. Dust (150 grams No. 1 St'd. and 5 lbs. No. 2 St'd.) from previous runs left in.

NOTES TAKEN FROM THE TEST RECORDS[4]

Cleaners nos. 3, 4, and 26, Dailey.—The intake cone furnished regularly with this cleaner *was not in position* during any of the tests. Its effect would be to increase efficiency and vacuum slightly and to lengthen a little the time between clean-outs.

Cleaner no. 4.—The vacuum measured by 18 inches water (read after 150 grams no. 1 standard dust had been fed in) dropped to 10⅜ inches when the cleaner was jarred with wooden mallet.

Cleaner no. 6, Donaldson Dry.—This cleaner is designed for a larger engine than the 25 h.p. machine used in the tests. After the runs on this cleaner, a large quantity of dust was found in shroud of cleaner. The efficiencies found were therefore higher than they would be after runs enough to fill free space in shroud.

Cleaner no. 8, Donaldson Water Type.—This cleaner should have a more obvious place for filling with water.

Cleaner no. 12, Palmer.—A trace of oil in very finely divided form was found on top cloth of absolute cleaner after each test. When motor idles or stops, oil settles into air intake tube in such quantity as to cause 'choking' of carburetor. This vacuum (fluctuating about 1¼ inches of water) might cause trouble in starting a warm engine.

[4] See also notes in tables of summaries.

Cleaner no. 15, Stewart-Warner.—At the end of dust feeding in fill-up test, vacuum due to cleaner was measured by 16⅛ inches water. After seven minutes longer run without more dust, vacuum decreased to $14^{13}/_{16}$ inches. One side of cleaner was almost completely clogged because of the rapid rate of feeding. Some iron rust was found in this cleaner, and it may have contributed to the clogging. The later cleaners of this make are made of brass.

Cleaner no. 19, United Manufacturing and Distributing Company Ejector.—A test of length of life of the bearing was run on this cleaner, twenty-five cubic feet per minute air being drawn through by vacuum cleaner. Time 216 hours before the efficiency tests, 315 hours after. Total 531 hours. Cleaner chattered a good deal toward close of test.

Cleaner no. 23, Bennett Dry.—Run (no. 64) discarded as official service run, but averaged with runs 62 and 63 since dust from previous runs (nos. 62 and 63) probably dropped from interior walls of cleaner and passed on to absolute cleaner. If cleaner had been shaken during and at close of runs 62 and 63 this dust would have reduced their efficiencies. Dust (dry) removed from cleaner after runs 62, 63, and 64, totaled 61.90 grams.

Cleaner no. 25, Stromberg Ejector.—With normal load and speed and with cleaner outlet and inlet disconnected from other apparatus and closed, expirator produced a vacuum inside of cleaner body measured by 12⅜ inches water.

Pressure of exhaust gas in pipe one inch from cleaner was measured by 11½ inches water, average, during first tests on this cleaner. During the last tests it was about 4½ inches. The difference is due probably to a slight change in the point of exhaust manifold where gas for the cleaner was piped out. It is interesting to note that the cleaning efficiency is unchanged. After the seven runs, a carbon deposit about $1/_{32}$ inch thick was found in the throat of the expirator.

Graphs.—Figure 6 shows graphically the dust separation efficiency of the cleaners tested, and makes possible comparison individually and by groups. Fig. 7 makes possible a similar comparison with respect to the choking effect and how this changes as the cleaner takes in more and more dust. It will be observed that for the large majority of cleaners the vacuum is less than ten inches of water and either constant or nearly so, while for a few it runs up very rapidly. Fig 8 shows the effect of each of the several cleaners (when clean) on the power of the engine and the effect on the vacuum when the engine is giving maximum power. The curved line (used in each of

the four parts of fig. 8) was obtained by measuring the maximum power obtainable from the engine, first with the carburetor unobstructed, then with its intake closed more and more by a gate valve. The object of this test was to learn whether the effects on power of the several cleaners were due only to the vacuum they produced or to some other cause. It should be pointed out that, while the utmost care was used to avoid errors, the results are not conclusive for the reason that the effects of the cleaners (*when clean*) on power are so small that it is possible that slight changes in the engine itself may in some cases have had more effect than the presence or absence of the cleaner.

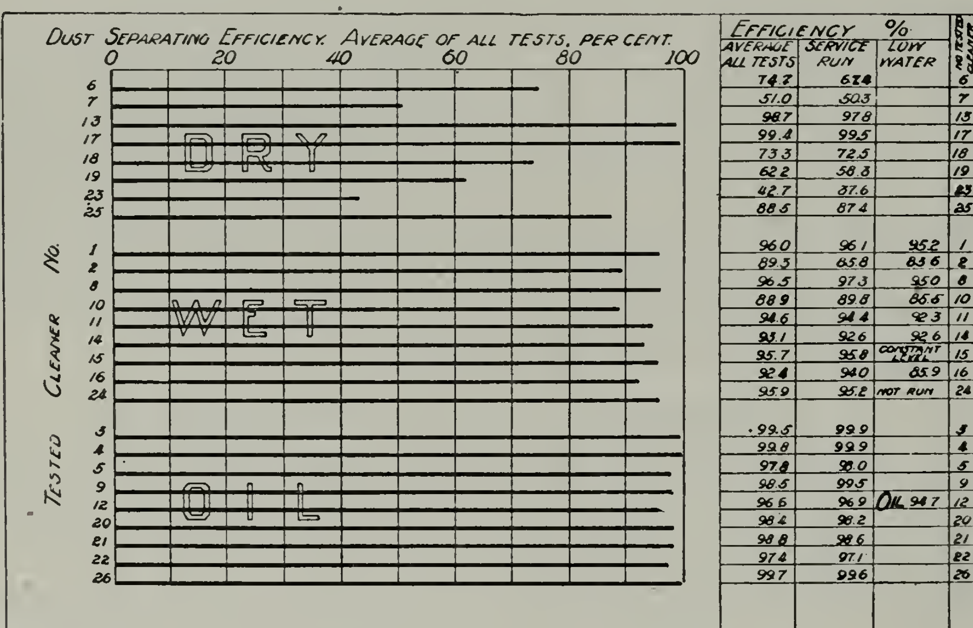

Fig. 6.—Graph of dust-separation efficiency.

Vacuum effect not entirely harmless.—While it has been shown that none of the cleaners if clean has very much effect on the maximum possible power of the engine, it must not be assumed that the vacuum effect is entirely harmless, especially if it increases as dust is absorbed by the cleaner. If at full load of the engine the vacuum be above about 10 inches of water and the needle valve of the carburetor be set for correct mixture, it will be found (in the case of some carburetors) that at half-load the lower vacuum and hence less suction on the gasoline jet will make the mixture much too lean, possibly causing back-firing and even stoppage of the engine. If it be adjusted correctly for light load, the mixture will be altogether too rich at full load. Thus the high vacuum will cause one or the other of two undesirable conditions: either the mixture will often

be much too rich (with consequent waste of fuel and rapid carbonization of spark plugs and inner walls of the combustion chambers), or the operator will be under the necessity of adjusting the needle valve too frequently. This will be the case for variable load, e.g., a tractor on drawbar work. For belt work with steady load, e.g., running an irrigation pump, a vacuum measured by 10 inches or even 15 inches of water is not serious.

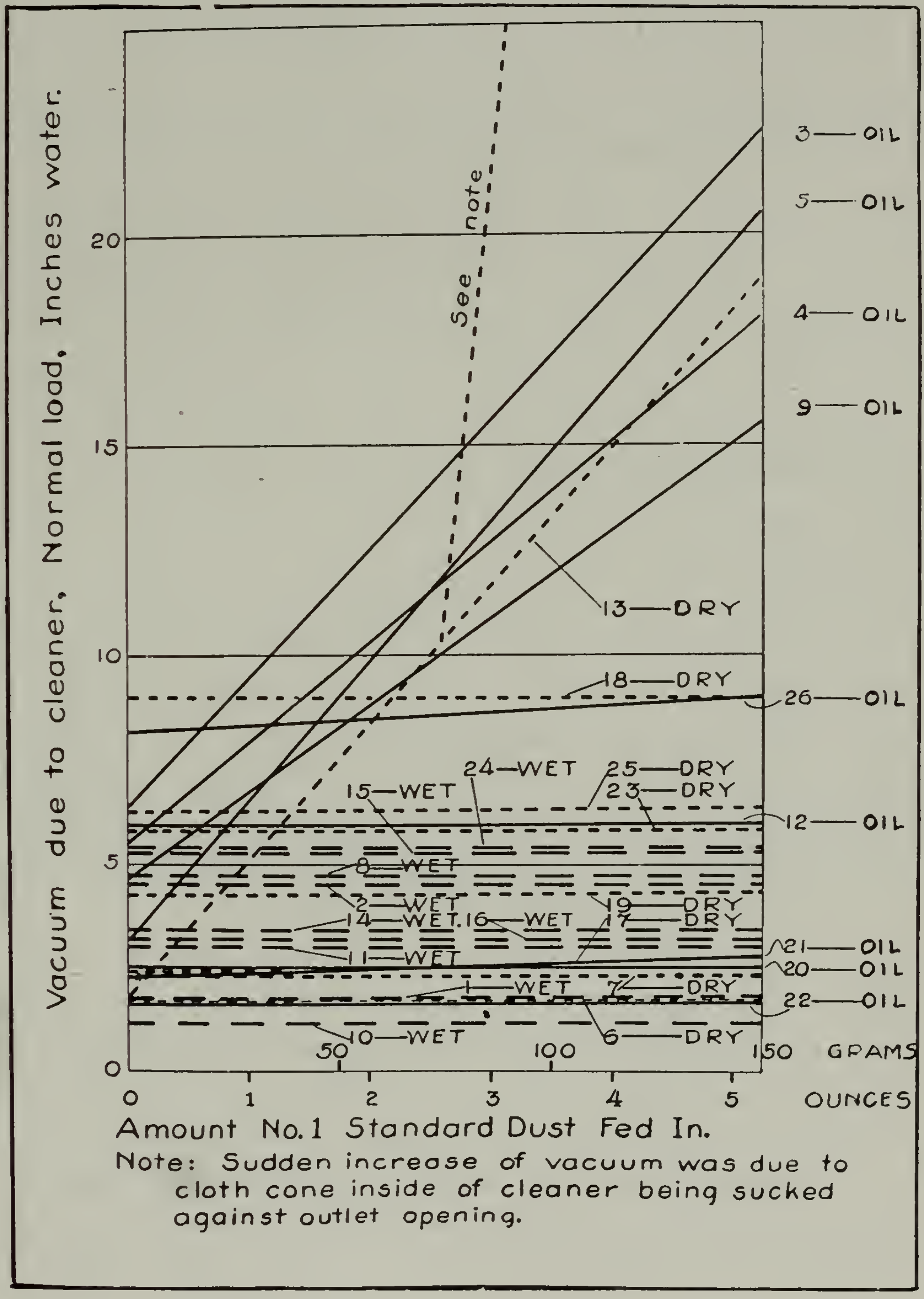

Fig. 7.—Graph of vacuum or choking effect. A line rising as it passes from left to right indicates a cleaner the vacuum of which increases as dust is absorbed.

HOW TO GET BEST RESULTS FROM AIR CLEANERS

No leaky connections.—No leaky connection should be permitted between air cleaner and carburetor or between parts of the air cleaner itself. A loosely fitting slip joint or an ordinary flexible metal tube are almost sure to admit some air and a great deal of dust. A piece of radiator hose fitting tightly over the tubes to be connected is very satisfactory if the connection is short. If long and the vacuum rather high, the hose walls may be caved in by the air pressure and thus the passage be obstructed. In such a case the line may be spliced, a thin metal tube making up the larger portion of the length. Ordinary friction tape is a very satisfactory emergency material for stopping air leaks.

Filters, whether of cloth or fiber, cannot be efficient if they have holes in them. The dusty air will go in largest quantity by the path of least resistance. The dust will find the hole if there be one.

Breather pipe should have clean air.—A special cleaner[5] may be used or connection may be made to the carburetor air cleaner. If clean air is not provided, the breather pipe itself acts as an oil-type air cleaner taking in breaths of dusty air, collecting the dust and sand on the oily walls, then blowing out puffs of clean air. When dust goes in through the carburetor there is a chance that some of it may escape through the exhaust. Not so with dust on the walls of the breather pipe. It remains until the oil washes it down into the crank case. When it is not feasible to connect the breather to the air cleaner, a small bag of eiderdown blanketing or cotton flannel, lint side out, may be tied over the breather pipe. This will remove one leading cause of rapid wear of timing gears, front piston and cylinder and front main bearing in some tractors.

Place air intake high.—Except in orchard work it is usually possible to use a 'periscope' or high vertical extension for the air intake. The advantages are that the quantity of dust to be removed by the air cleaner is greatly reduced and that the coarser dust is avoided. Some air cleaners are regularly furnished with a jointed periscope. Part or all of it should be used whenever feasible. If a periscope is provided, it should be smooth inside and free from sharp turns. The inside diameter should be amply large (not less and preferably more than 2 inches for a 10–20 tractor), or the vacuum effect will be unnecessarily increased.

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[5] The market affords breather air cleaners for certain tractors. Manufacturers' addresses will be furnished on request.

Give needed attention.—There is not on the market, so far as the writer is aware, any air cleaner that can be put on a tractor or automobile engine and forgotten and yet month after month give adequate protection against dust. All require some attention and have their own peculiar troubles. Those with moving parts have troubles due to wear and to accumulation of dust and oil. Thus the float in some water type cleaners may have holes worn which would permit dusty air to pass without going through the water. Centrifugal types

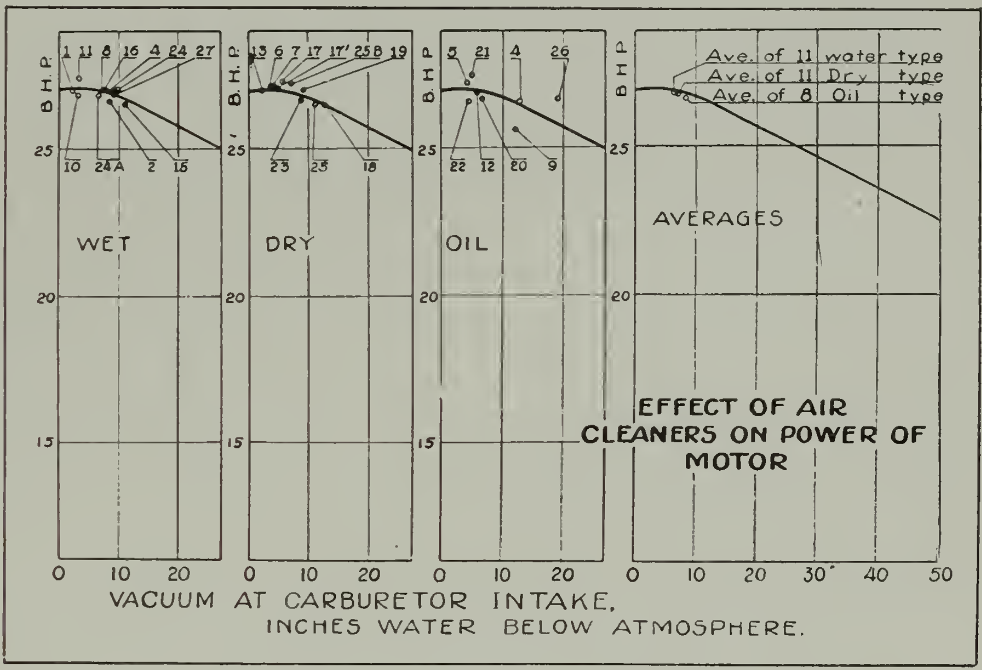

Fig. 8.—Graph of effect of air cleaners on power of engine. The curved lines show how power falls off as carburetor intake is choked (no air cleaner on). Distances up show brake horsepower, distances to right show vacuum or choking effect measured in inches of water. Maximum power with cleaner off was 27 h.p. Each cleaner's effect on power and vacuum is shown by position of the numbered points.

may become so encrusted with oil and dust that their action may almost entirely cease. Cleaners having small passages inside may clog up solid. Other kinds may so increase their vacuum effect due to accumulation of dust that the power of the engine may be greatly reduced. Nearly every air cleaner has its plate giving the manufacturer's directions for the care required. Some tractor operators may be able to improve upon these directions, but none may safely neglect them.

A SIMPLE EFFICIENCY TEST FOR AIR CLEANERS

Not what the air cleaner catches, but what it lets go by does the mischief in a tractor engine. Whether any appreciable amount of dust gets past an air cleaner may usually be known by disconnecting the air cleaner from the carburetor and wiping out the inside of the connecting tube. If after a ten-hour run under dusty conditions only a trace of dust can be wiped out, the cleaner has probably done a first-rate job. This test may fail, if, as might possibly happen, so much water or oil should go over from the cleaner that the tube would be kept washed out.

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